

The Use of Technology in the Mathematics Classroom

An Honors Thesis (HONRS 499)

by

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A handwritten signature in cursive script, reading "Donald R. Whitaker".

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Abstract

This examination of the use of technology in the mathematics classroom will be composed of two elements: a review of pertinent literature concerning technology and a case study of technology in two high schools. Beyond the literature review, this analysis will attempt to synthesize ideas and compare the contemporary opinions regarding technology use in schools. Finally, several teachers were engaged in a discussion relating to technology. They were all asked the same questions and their responses have been collected for this project.

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Introduction and Purpose

The dawn of a new era of computerized instruments faces the world today. Our technological complexion changes with such frequency that it is difficult to stay abreast of the latest developments. Computers and other types of mechanical devices, rarely dreamed of years ago, now are commonly used, not only in the workplace, but also in the homes of a growing number of individuals. It appears their use will continue to increase in the coming years. The use of technology has also spilled over from these areas into a growing number of today's schools. However, administrators, teachers, and communities have failed to reach a consensus concerning the extent of technology use in schools. Many individuals possess strong feelings on the use of technology in the classroom. Both sides of the debate have only the best interests of the students in mind, but there exists a noticeable gap between its proponents and opponents concerning the range of its use. The same diversity educators often celebrate now leads us to an intriguing discussion to determine the most appropriate ways to instruct and guide our students. Thus, the purpose of this paper will be to review the many issues concerning technology in the classroom. More specifically, this examination will focus on technology in the mathematics classroom separate from other academic studies. For clarity, the definition of technology also will be restricted. The term technology will refer to the use of calculators and computers in classroom instruction.

Review of Pertinent Literature

A report from the United States Department of Commerce during 1995 indicated that in order to provide our students with the skills sufficient to keep up in our world

today, they must be exposed to various types of technology in the school setting (No Author 1995). Many educators echo this argument in their support for an increased use of technology in our schools. They believe the changing times and requirements placed upon the shoulders of today's students must be met with increased use of technology. The business and professional worlds now use technological equipment at an exponentially growing rate. Thus, in order for students to use technology successfully, they must be exposed to it while in school. This claim represents one of the major arguments for the increased use of technology in schools. Students must familiarize themselves with technology to prepare for future endeavors.

The other chief argument, which ultimately holds more validity in schools, involves the increase in comprehension and learning that technology may provide for students. The teaching methods that were used in years past must now be revised to accommodate the recent developments in education. Technology can help create a more active learning environment when used in conjunction with organized instruction. Possible outcomes from this new environment are an increase in student motivation, interest, and ultimately comprehension of information. These ideas will be more thoroughly analyzed later in this paper.

Although some individuals do not eagerly embrace the idea of technology, other areas of the professional world clearly do. A study found that eight years ago was the first year in which the monetary amounts spent for technological equipment surpassed the financial costs for other fields including the following: "industrial, mining, farm and construction machines" (No Author 1995). This same study reports that the percent of workers who must use computers on the job nearly doubled between the middle 1980's

and the early 1990's. Furthermore, it stated that twenty years ago only 50,000 computers existed in the entire world, while today more than 50,000 computers are sold every ten hours (No Author 1995). These numbers and others similar indications show that these trends will only continue to increase as technological equipment becomes more affordable, more effective, and more widely accessible.

The United States Department of Commerce study clearly expresses the feelings held by many individuals:

“The work force of the 21st Century will need to be familiar with information technologies, adept at information gathering, and comfortable with the manipulations and interpretation of data. In order to help prepare and train much of tomorrow's labor force, education institutions will need to be equipped with information technologies and communications networks that are integral to these processes. Students who do not learn to use computers and information technology in schools will not be competitive in the job market” (No Author 1995).

Thus, students must be exposed to various technological instruments in school to adequately prepare them for the future.

Mathematics educators claim that a shift in modes of practice must occur if we are to adequately prepare and challenge our students for tomorrow rather than yesterday according to Iris M. Carl, guest editorialist in Electronic Learning (Carl 1995). We do not communicate, cook, clean, or truly exist the same way we did 15 years ago. Thus, why should we educate our students the same way we did 15 years ago? By retaining our old methods of teaching, we do not sufficiently prepare our students to deal with their future ventures. Teaching is a dynamic process in need of constant evaluation, and many individuals believe that the current educational system is not functioning, as it should. Technology helps provide and improve the opportunities our students have for future careers (Carl 1995). These observations do not suggest that we eliminate all past

methods of instructing, but they do stress the necessity of improving and refining those methods.

One possible reason the opposition exists to reforms in the educational system lies in incognizance. The general public may fail to see the need or the benefit of this increased technological use. Many individuals often believe they were educated without calculators and computers, and that their children should be educated likewise today. Thus, we must clearly demonstrate the need and the benefit derived from technological instruction. As emeritus professors, Bert Waits and Frank Demana of Ohio State University eloquently state,

“As educators, we need to communicate convincingly to the public that ‘doing mathematics’ in the twenty first century means much more than doing the mathematics of the past. School mathematics in the future will be far more technologically enhanced, richer, more interesting, and more applicable than in the past. Business and industry want employees who can think, read, and understand problem situations; work cooperatively in groups; understand and use technology; and communicate effectively with others” (Demana and Waits 1996).

These lofty goals dictate that an effective plan of instruction must be implemented to incorporate technology use. Teachers must still ask challenging questions, but they must also provide exploratory assignments that allow students to examine realistic problems in a manner perhaps never seen before. Furthermore, technology use can help achieve some of these high standards we set for our students and ourselves.

Importance of Mathematics

Recently, the general public and the members of the media have scrutinized education, specifically mathematics and science scores on standardized tests. The quality of students graduating from high school has come under fire. Studies show only fifty

percent of graduating seniors have proven themselves proficient at middle school arithmetic and less than ten percent have sufficiently performed senior level mathematics (Carl 1995). One can clearly see the problems embedded in this data. The blame may be passed from administrators to the students. However, ultimately the teachers shoulder much of the criticism.

The same studies noted above report that nearly three-fourths of lower level business and industrial positions demand some understanding of algebra and geometry. The door closes on more than 20 potential career choices for those individuals who have not completed at least three years of mathematics at the high school level (Carl 1995). Thus, the importance of a mathematics education for students cannot be overemphasized. Some critics argue that there is little need for much of the mathematics learned at the high school level. However, these statistics seem to suggest the contrary. Individuals can infer that there exist legitimate reasons to instruct our students in mathematics. Mathematics is one key to a successful future for our students. In addition to the content, the study of mathematics helps stimulate the cognitive and analytical aspects of the students' minds. The procedural and structural methods of solving problems used in mathematics can be applied to other situations occurring in life.

It is a well-known fact that individuals change their minds and career directions numerous times throughout their lives. With the uncertainty of many companies' futures that exists today, individuals often change occupations throughout their post-collegiate employment. Individuals must keep as many doors open as possible. Tomorrow's workers will need to be flexible and multifaceted in their abilities. By closing doors early in life, students may be cheated from a potentially prosperous and fulfilling career. The

more skills the students leave school with today, the more adaptable they will be to the ever changing tomorrow. As Iris Carl said, “mathematics is a gateway to a life time of opportunity for many of our students” (Carl 1995).

Importance of Calculators

Calculators have been in existence for decades, and they have been used in classrooms for nearly the same duration. Calculators can help relieve the burden of cumbersome calculations and can help students focus on the actual process of solving a problem. They can help students explore, develop, and uncover knowledge that exceeds the level attainable with standard paper and pencil instructional methods. Calculators allow for a more laboratory-based experience with activities concerning experimentation and manipulation using contemporary issues and data. John G. Harvey (1991) found that students can effectively be asked to uncover patterns, make conclusions, and predict outcomes based on an acquired set of information. All of these outcomes, if attainable with the use of calculator technology, can provide great benefit to the understanding of mathematics’ roles in society.

It is evident that many individuals place elevated expectations on the classroom use of calculators. However, many wonder, as educator Maggie Hill does, why although technology use in the classroom is supported and cheered by numerous individuals, there still fails to exist a true strategy concerning use of technological instruments such as the computer in the classroom (Hill 1993). Many critics argue we have not done enough to demonstrate how to incorporate these new resources available to us. Bill Masalaski, a National Council of Teachers of Mathematics (NCTM) board member and leader on the

technology committee, states candidly that we are lacking a firm grasp on technology and that we must continue to work to catch up to the changing times (in Hill 1993). Teachers can possess the greatest resources, but if they do not know how to use them effectively, their resources render themselves futile.

Arguments such as those above do not clash with the use of technology in the classroom, but they do stress the importance of proper guidance and education, as well as a critical analysis of when to use technology and how best to apply it. Teachers must understand their actions and the reasons behind them before they can truly educate their students. They must also understand the resources they use with students. Thus, professional teacher development and in-service education regarding technology can provide appreciable benefits to teachers, and ultimately, their students.

Calculators versus Computers

The question of calculators versus computers often arises in debates concerning educational technology for the mathematics classroom. Schools struggle with the issue of which is more important or even necessary, calculators or computers. Because of fiscal concerns, school systems must be judicious in what resources they acquire. Some vocal proponents of calculators, including former NCTM president Mary Lindquist, stress the need for calculators over computers, noting that because every student can more readily possess a calculator, calculators can have a more significant impact on education (in Hill 1993). Obviously, the computer exposes students to a wider and more diverse array of possibilities, yet size, price, and accessibility limit the use of computers in comparison to calculators.

To help accomplish our dreams for our classrooms we must better equip our teachers with not only physical materials, but also with conceptual and procedural knowledge. The more teachers become educated on the possibilities of technology for educating, the more they will realize the wealth of opportunities available. Teachers will have to grow and learn with the technology to help develop the educational system and guide the students today. Teachers cannot be expected to shoulder the entire burden these new teaching styles will create. They are already asked to complete an enormous amount of other work ranging from administrative tasks to extra curricular activities. Thus, their abilities and actions are already stretched to the proverbial maximum. They must be given some assistance from the administration that guides them.

In the past teachers have been neither discouraged nor overly encouraged to use technology in the classroom. If they sought out information concerning its use, then they used it. However, this situation has been detrimental to those teachers lacking the time, resources, or ability to understand the extent of technological capabilities available to them. Demana and Waits (1996) observe that many educators refrain from the use of certain technological instruments because they have not been “practical or possible.” Yet, this perceived obstacle can be overcome. Teachers must be helped and encouraged to use the best of what is available to them and their students. Demana and Waits (1992) go on in another article to note teachers should be provided the opportunity to work with the best materials to instruct their students, and not be forced to use less effective manipulatives.

Calculators and computers should be found in every classroom or least available to everyone who desires to use them. Classrooms structured around technology may be

our best chance to instruct our students effectively. The resources are available, and they must be used to benefit our students. School systems must find the financial means to fund technological development. They might not begin with the best computers or software. However, they must begin somewhere. Small beginnings followed by incremental steps can lead school systems to a future of success. These instruments can help the students visualize and understand the intricacies and usefulness of various mathematical concepts and applications (Demana and Waits 1992).

Economic Affordability

As with everything in our world today, the economics of technology must be considered before making a decision concerning its use in the classroom. Many individuals claim that schools in economically secure and technological advanced environments will have a wider selection of resources available than inner-city schools located in financially threatened environments (No Author 1995). Though this statement probably holds validity across America, it is hard to argue against technology because of this fact. To withhold technologies from those students in affluent locations does a disservice to their education. A report by the General Accounting Office found that schools with a majority of minorities are found to lack appropriate technological resources (No Author 1995). Academic leaders and government officials must do their best to bridge the gap that exists between the rich and poor. This same study found that families with lower incomes living outside of the cities have difficulty providing the same products to students where they spend the majority of their academic-related time: home, schools, and libraries (No Author 1995). Thus, ideas must continually be

discussed on how to improve the situations and conditions facing the entire educational community.

One possible solution to the problem indicated above is to require schools to furnish students with graphing calculators, especially those who are unable to afford them (Demana and Waits 1992). The recommendation may be to increase book rental fees or to waive the fee entirely. All students may not be able to have their own computers, but graphing calculators are highly advantageous machines that can be taken to any location in a rather easy manner (Demana and Waits 1992). Thus, schools can replace computer instruction with the effective use of calculators. Calculators cost much less than computers. For many school systems, it may not be possible to have numerous computers, but students can derive a wealth of knowledge by using graphing calculators. Many students lose out if teachers must use only computer equipment to instruct their students through a technological medium (Demana and Waits 1996). However, if the students rent their calculators, they may not be able to take them home to help with their work. This drawback, while not fatal to their education, does limit the possibilities available.

The onus of responsibility rests on the schools to provide students and teachers with the technological equipment they cannot afford. Computers and calculators as a tandem can provide great benefits to any classroom. However, because this combination may not be financially feasible, the suggestion has been to focus on the use of calculators, which are less expensive, and if effectively used, can also help students achieve a great deal of success. Furthermore, as prices continue to decline, more and more resources will become affordable to a wider selection of schools.

Students Per Computer/Calculator

The ideal number of students per unit of technology differs from teacher to teacher. Some teachers claim that with calculator use it is important that each student, or pair of students, work with a calculator. However, with computers, teachers' ideas to vary more. Group work helps students learn the values of working cooperatively and assimilating each other's ideas to achieve higher degrees of learning than is possible individually. Each member brings different ideas and backgrounds to the group. Those involved can better themselves if they take these differences into account.

The first important idea behind students working with technology is to ensure that the students actually engaged themselves with the technology. Aarstad (1997) found the most success when the students were allowed to discover the technological possibilities and then share them with others. Too often, he believed, teachers fall into the trap of attempting to show students everything. Teachers must allow students to make mistakes and struggle while solving problems. The obstacles that students overcome will better prepare them to accomplish more in their academic studies. On the other hand, teachers must invest some time and effort to introduce the technology to students. Aarstad (1997) also found that students who were not introduced to the technology often spend more time playing with the machine than utilizing its power. He also learned that the reward for spending some amount of time introducing the capacity of this tool will be an increased knowledge base with which to develop new ideas. Though he worked with an algebra class, the same ideas could describe an unfocused group of students in any math class. Students must be allowed to discover some ideas on their own

Aarstad (1997) also found that motivation increased for the students and the learning the students acquired was high, exceptionally so in some cases, in his TI-92 based classroom. Students can discover or solve problems in their own way and help their classmates with their newly acquired knowledge. The independent and group work allows for more differences in the structure of each project. Students can have greater freedom to explore the material in the way they see fit. Classmates raise questions and ideas perhaps not thought of before, and thus a different way to derive answers may be discovered. The teachers cannot ask all of the questions. The students, to achieve a higher degree of knowledge, must be able to pose questions they arrive at while working with the technology. This process of proposed ideas and work can lead to a deeper understanding. Students begin to take great pride in their achievements and accomplishments when using technology. They have achieved a task and solved a problem that may have been difficult, if not impossible, to solve before the advent of technology in the classroom. After all, teachers want students to attain some level of intrinsic motivation to help them pursue their academic studies.

To have any noticeable effect on students' learning, the use of technology cannot be a once in a great while occurrence. As with exercise, sporadic, non-regular activities using technologies will do little to help the overall learning. Students must work with computers and calculators on a regular basis to gain any true guidance from them. The more students work individually and with small groups on these problems the more they will be aided. They will become more familiar and comfortable with the possibilities of a calculator in education. A classroom organized in this way becomes open one centered on collaborative learning with a focus on the students. There will be fewer textbook only

assignments and more creative explorations. The entire atmosphere of the class will change.

The journey has only begun once the technology has been provided in the classroom. Students must remain active in their participation with the technology. They must understand the results and the accuracy their technology derives for them (Aarstad 1997). Students cannot just accept the answer given and move on to the next problem. They must be able to interpret the answers they obtain, and determine their significance. These technologies help make the information gathered seem more worthwhile and educational. Carl (1995) observes that in such situations students can now develop their own understanding and comprehension of the topics the class is dealing with as a whole. Their education becomes more individualized and personal, thereby making it more meaningful.

As mentioned previously, the more students deal with authentic mathematical concepts, the more effective they will be in adapting their knowledge and skills to other academic and social fields (Heid 1990). Students become true problem solvers, not just in the area of mathematics, but in life. They are therefore able to apply their newly found knowledge to other situations and solve problems they were unable to solve before.

A teacher may feel uneasy about the move from a teacher-centered classroom to a more student-centered one with the introduction of technology. However, this perceived drawback will actually render itself a benefit the more the students and the teachers become comfortable with it. The questions they ask are better than any question you will find in a textbook or ones the teacher could ever come up with. However, the teacher must be able to say that they do not know the answer to every question. Teachers must

realize the newly thought of questions can only benefit the academic growth of each and every student in the classroom. They will ask difficult and probing questions that will delve into the basis and foundation for mathematical operations. They will want to know why things happen this way, and what will occur if some aspect of the problem changes. These opportunities allow for exploration and extension into the wonderful world of mathematics and the pearls it has to offer. Teachers must embrace these moments and encourage their students to continue down the path of learning even if the end is not always certain (Dick and Dunham 1994). The entire landscape of the classroom changes with the active exploration using technology.

All of these ideas noted above could not be possible without the advent of technology in the classroom. Calculators and computers provide the medium for these goals to be accomplished, but teachers are still the key players. They must actively and continuously challenge their students in the learning process.

Motivation and Technology Use

Motivation becomes a double edge sword in instances surrounding technology. According to the study by Aarstad (1997), calculators and computers have been used to generated excitement and enthusiasm for material that has previously been considered difficult. Students no longer have to worry about the stress of performing numerous, complex calculations because the calculator can perform operations in a timesaving and accurate fashion (Aarstad 1997). Students often become frustrated when dealing with complex problems. They lose interest and give up too easily during difficult mathematical problems. Technology creates more equality for all students when solving

mathematical problems. However, using the calculator or computer to solve problems does not ensure that students will understand the material. They must comprehend why problems are solved the way they are and what the answers truly represent. Without this knowledge, any information attained is meaningless. Teachers must ensure that students understand the process. However, the technologies allow students to concentrate on the overall setup and solution of a problem, rather than the detailed and tedious computations.

They same study mentioned above found “evidence for the following claims: a) skill in calculation increase b) motivation for working with subject increases c) problem-solving ability is stimulated d) professional understanding increases, making it easier to solve professional problems” (Aarstad 1997). These four goals are ones teachers strive to achieve in all of their students. If the results of this study are correct, then technologies such as calculators and computers represent essential components we must implement in to our classroom. In another study, students commented on the successfulness of using calculators during their instruction. Individuals said “...it [math] became more interesting,” and “you can see the entire thing more clearly” (Bethell and Miller 1998). These comments reflect a change in the traditional stereotype of mathematics being a boring subject.

Mathematics has commonly been thought of as a field pursued more by men than by women. However, the study by Aarstad (1997) found that women, in particular, changed their feelings toward the calculator when used as an instrument in the mathematics classroom. In this study, the first weeks were characterized by a rather poor attitude towards the machine’s capabilities. Yet, as time moved on, the attitudes of the

students gradually warmed up to the possibilities that now faced them. Inclusion of not only special needs children, but also of different sexes is a goal of all education.

Teachers must do everything possible to involve all of our students, regardless of sex, race, or religion. Technology seems, at least in this instance, to help accomplish this goal.

Another important issue revolves around the phenomenon of calculator reliance and the decline in motivation that comes during assignments without the calculator (Aarstad 1997). It is important that teachers think about how much time should be spent using the technologies. Some teachers argue since the technologies will be available in the professional world, they should be available today without much concern about the motivation. Other teachers, however, claim that students must be able to master and perform the tasks without the technology available to them. Teachers seem unanimous in their steadfast belief that students need to understand many of the mathematical processes. Thus, the issue is not easily resolved. Teachers must use their best professional judgement in order to decide what is most appropriate for their students.

Technology use is not the cure-all of instructional problems, but it does represent a positive step forward in the opinion of some teachers. Kalman (1994) states that studies have found that students' self-esteem increases, stress is cut, and time becomes more in students' control (Kalman 1994). In a discussion-centered classroom there are endless possibilities. In classes where the calculators were used to full advantage, students attained a higher level of comprehension and knowledge according to Dion (1990). Students in these classrooms were not just given operational problems to solve. They

utilized discussion, collaborative work, and authentic assessment to help develop the students' minds.

When to Use Technology?

Another decision facing teachers that relates to motivation is when and when not to use technology. When is it better to use paper-and-pencil methods to accomplish the goal of teaching our students? It must first be understood that mathematics instruction is different today than it was years ago. This fact was mentioned previously, but its importance lends itself to be mentioned again. The way we look at our instruction must also be different.

Time is an overriding aspect of this debate. When information can be taught more quickly and effectively using technology, then by all means, technology should be used. However, the debate extends beyond the issue of time. Mary Ann Matras, a professor at East Stroudsburg University, posed the following questions to herself:

“When do we begin to use technology in the mathematics classroom? Whenever and wherever the technology allows students to do mathematics more efficiently and effectively. When do we end our explorations of the use of technology in the mathematics classroom? Not when we have learned to do all the old things a little faster, but when we have found new ways to do mathematics and ways of doing new mathematics while using technology to its fullest potential” (Matras 1991).

The answer seems to go beyond the time factor and into a more complex aspect of teaching. This aspect involves doing mathematics in ways that will allow our students more opportunities for discovery. Calculators and computers should not be used exclusively to lessen the time required to perform tasks. However, the time aspect is

often a major focus when considering technology use. Calculators and computers should lend themselves to new, exciting ways to solve problems.

We must also realize that there may be times when technology use is not more effective or efficient than paper-and-pencil methods. In these situations we must use these latter methods to instruct and educate our students. James Landherr, the mathematics coordinator for the East Hartford, Connecticut Public Schools says that he does not want to see computer use because of the availability it provides (in Hill 1995). Technology represents a useful tool that should be used for a specific purpose of educating. It must not be a tool we use because its there. It must appropriately serve some intent to benefit our students. Thus, even when we choose to use calculators or computers in our classroom we must be able to justify its use.

The fact remains that in the professional world, technology is more prevalent than ever before. We use computers and calculators for all sorts of purposes. Therefore, we must change our methods of instruction because technology can radically alter the way our classrooms can function. Learning can become more of a hands-on experience for our students. However, we must make certain that technology is used for learning and not for its image and glory (Cuoco, Goldenberg, and Mark 1994). Calculators and computers should not represent status symbols for school corporations. It is not a competition to see who can attain the most “toys.” Also, we must recognize the difficulties in motivating our students to use paper-and-pencil methods when technology is available. Teacher judgement and teacher abilities must be developed to the highest degree in order to achieve competence in these areas.

Assessment

How will assessment change in technology-based classrooms? Obviously, the questions that teachers ask during testing will have to change. The same basic calculations will not be included unless use of technology is prohibited on tests. As Harvey (1991) observes, “when we do not permit students to use their calculators on tests, we should be sure that (a) the content being tested has not been taught using calculators and (b) the paper-and-pencil skills and algorithms tested are ones that students will need to know and they have been taught.” It is neither fair nor wise to assess student performance without calculators or computers when they learned the material using these two tools. Harvey also observes that teachers must remember which material they instructed, practiced, or performed operations with using a calculator so as not to inappropriately assess the students. The teacher must be acutely aware of these ideas while assessing student progress.

Test questions must challenge students to go beyond the basic computational type of problems. The questions must delve into the understanding and the application of ideas to various situations. Writing and talking about mathematics should work itself into the classroom. Therefore problems in which the students read and comprehend what they read must be used.

The advent of certain technologies will require teachers to use alternative methods of assessment. Portfolios will become key documents in most classrooms. Students may be asked to compile a collection of their best works and offer explanations of why these works exemplify their abilities. They might show progress by including earlier drafts and tests to show how they developed throughout their studies. Assessment can also be done

through projects, presentations, and interviews. The professional world uses these types of techniques, and these represent ones that can benefit the student immensely both in and out of school. Although not an exhaustive list, these examples represent some of the alternative assessment methods available to teachers. The list is only limited by the creativity of teacher's mind. Yet, all of these techniques can incorporate some use of calculators or computers to exhibit student mastery of knowledge and skills.

This section of the paper has reviewed the pertinent literature related to the widespread use of technology in mathematics education. The next section describes a case study of technology use in two specific schools.

Case Study of Two High Schools

In order to determine how technology is actually being implemented in high school mathematics classes, two Indiana schools were selected for an in-depth case study. The goal was to interview mathematics teachers in each school and learn about their use of technology-past, present, and future.

School A was a large, urban high school of 2200 students located within a major metropolitan area. The mathematics teachers who were interviewed in this school all had over fifteen years of teaching experience at not only School A, but also at various other schools in and around this metropolitan area. School B was a mid-size, suburban school of 800 students located near a major university. The mathematics teachers interviewed here had teaching experience ranging from three to twenty-nine years. It was believed that the diversity of the two locations and the differences in teacher experience would provide appropriate contrasts for the study. Only one female instructor was interviewed

at School A, and no female instructors were interviewed at School B. As a matter of fact, School B did not have any female mathematics teachers. Although not directly related to this study, this fact should be mentioned before the analysis continues. The next several sections describe the results of the interviews. All teachers were asked the same questions.

How have the technological resources and the views by teachers directed towards these resources changed over the last five years?

Teachers in both schools stressed the growing benevolent attitudes towards technology use. They indicated that every year more teachers increase their use of technology in their classrooms. They understood that attitudes and uses will continue to change, but they seemed confident the use would continue to grow. One teacher from School A engaged in a discussion concerning the correlation between the age of a teacher and the extent of technology used. He stated that veteran teachers are reluctant to use technology initially because they have seen teaching fads come and go over the years. However, he does believe technology will continue to be used in the classroom. He is a veteran teacher, at age 50, but he uses technology for numerous purposes in his classes. Teachers also stressed that although the use of technology will continue to rise, it will never replace the human presence of a teacher in the classroom. They emphasized that the teacher brings too much life and interaction to the classroom to ever be replaced entirely by a machine.

School B raised the issue of money and its effect on the attitudes of teachers toward using technology. This school did not appear to have a large portion of their budget dedicated to technological equipment. Thus, their attitudes have not always been

favorable towards the use of technology. However, they believe that as the equipment becomes more affordable, the attitudes will become more positive. Financial concerns also affect the second question concerning available technologies at the schools.

Describe the various technologies available at your school and how your school decided which items would be purchased.

School A, where funds for technology seemed to be more readily available, had over 500 computers and also had more sets of calculators, both graphing and scientific, for their mathematics students. Although an examination of the school the budget was not part of this research, funding seemed to exist for these technological purposes in School A. They maintained an impressive display of technological instruments. Teachers claimed their initial commitment to technology was somewhat of a leap of faith. They did some research and talked to other educators, but at some point, the department head pointed out, teachers just have to experiment and see what happens.

On the other hand, School B has only one laboratory equipped with approximately 30 computers for student use. Each teacher has a computer, but these are used basically for administrator duties. The school has few graphing calculators, although each teacher has a set of scientific calculators. School A was discussing how to get more TI-92 calculators, while School B was attempting tries to obtain funds for the less powerful TI-82 calculators. The differences in the two schools were apparent. School A, because of more funding and more students, possess more computers and calculators then School B.

How is the technology used in your classroom?

Computers seemed to be utilized more in School A than in School B. Some diversity in use also existed in School A. One teacher used the computer for tutorials and review sessions for her students. The other two teachers used the computer to incorporate spreadsheets and presentational software into assignments. These assignments seemed to be directed towards the authentic aspect of projects that is discussed so much today in contemporary mathematics education journals. School B, on the other hand, confined their technological use to the calculator. None of the teachers at School B used computers to any great extent. It was hard to determine whether this was a result of difficulties in accessing the lab, lack of training, or lack of encouragement.

What type of teacher development/in-services involving technology is available to you and which ones have you participated in personally?

Teacher development and in-service sessions related to technology were also quite different in the two schools. School A had ongoing developmental sessions, release time, and a summer grant program dedicated to technology. The school administration seemed to push teachers in the direction of exploring the use of technology in their classrooms. They were encouraged, as well as being given the services and rewards, to help them develop their technological abilities.

School B did not seem to have any directed technological in-service sessions. They had one in-service session every year to discuss their personal computers used for gradebook and administrative duties. However, none of the teachers could recall a workshop the school encouraged them to attend that sought to develop technological teaching strategies. On the other hand, a major university I located near this high school.

Although the school administration did not encourage their teacher to attend university related programs, such resources were available to teachers in School B.

How do you decide when to use the technologies available in your classroom?

Teachers in both schools stressed the importance of teacher judgement concerning when to use technology. They emphasized the importance of understanding some basic skills in solving various types of problems. This emphasis forces students to understand what the calculator or computer does as an aid to solving problems. The teachers in both schools were attempting to do something to increase the comprehension of the students. They understood that the final answer was not always the most important component in the classroom. The process the students participated in held the true benefit of their education.

How often (estimate) do you use technology in your classroom?

Both schools seemed to use calculators a similar amount of time. Obviously, School A uses the graphing calculator more than School B because they possess many more. School B requires the Calculus students to buy their own graphing calculators. These students used their tools more often than did those who only had them available in class. Various teachers had different ideas on when their students could use calculators. Some of the veteran and novice teachers allowed its use at all times, while other experienced teachers, restricted its use depending on the topics they were studying. There did not seem to be any correlation between the answer to this question and years of experience.

How many students work with each unit of technology? (student-calculator ownership, students-per-computer)

Various teachers offered different opinions on the matter. Some teachers wanted students to have their own piece of technology, while other teachers wanted students to work collaboratively with other students when using technology. They stressed the reasons for their opinions, but once again, they had similar ideas in both schools. The ideas presented previously were echoed concerning each teacher's belief as to how many students should use each unit of technology. Yet, it was once again evident that a consensus did not exist among opinions.

What advantages and disadvantages do you see in the use of technology in the mathematics classroom?

Teachers from both schools named some of the same advantages, as well as disadvantages of using technology in the classroom. The main disadvantage reiterated throughout the interviews was the fear that students may become too reliant on technology and that they do not really understand the processes involved in the problem. Teachers observed that students often felt they could not perform even simple operations after using the calculator or computer. They stressed the need to address this problem.

The teachers generally, they saw the advantages outweighing the disadvantages. They stressed the accuracy and time saved as among the benefits of using technology. They also stressed that students could now do more and worry less about tedious calculations. The technologies allowed the students more explorations and more hands-on experiences. The teachers felt as if the possibilities are endless concerning how

mathematics classes could use technology. However, they also expressed concern that sometimes they did not seem to have the direction necessary to accomplish these goals. They envisioned the overall result of using technology to be an increased in student understanding of the mathematics being studied.

Describe the changes in students' enthusiasm, learning, motivation, and/or success while using the various technologies?

Along the same lines of advantages the teachers saw an increase in student enthusiasm, interest, and participation when using technology. However, they saw these same accomplishments decrease when technology was not used. This issue resonates at the heart of the discussion that must continue on from this very day. Teachers must maintain motivational skills even when the technology is not readily available for the students. Also, students must preserve a desire to perform the operations when they are given a certain unit of technology. There does not appear to be a simple answer to resolve this dilemma, but it is one that must be examined continuously. Teachers must incorporate technology, but they must also find ways to motivate students when they are using calculators or computers.

What changes would you like to see implemented concerning the use of technology in your school?

Teachers in both schools expressed a desire to obtain more equipment in order to improve the mathematics education they can provide their students. Money will always be an issue, and it was once again mentioned as a concern. Yet, as technological equipment improves, one byproduct should be a decrease in cost. Additionally, teachers

in School B wished for more development and instruction on how to implement technology into their classroom. It seemed that having a nearby university was not enough. This idea is one that must be examined nationwide. Until teachers receive more instruction and guidance, it is difficult to expect them to utilize technology to its fullest potential.

Summary and Conclusions

Overall, teachers in the two schools provided insights into the use of technology in the mathematics classrooms. One can research for an extended period of time, but until one actually experiences the classroom setting and talks with teachers who deal with these issues firsthand; the knowledge gained will be somewhat limited. In the case study, there were not as many differences in the younger, less experienced teachers as some might expect. Yet, four of the six teachers were very experienced teachers. The veteran teachers seemed to state unanimously that the younger teachers, they believed, had more training, more ideas, and more of an inclination to incorporate technological tools into their lessons. A clear dichotomy did exist among the two different sized schools. In this case study, it seemed that larger was better in terms of availability and use of technological resources. This fact does not make one school superior to the other. However, it is another thought to contemplate when reviewing academic policies and funding.

The consensus taken away from these studies is one of unfinished business. The issue of when and how to use technology in mathematics education is ongoing and ever changing. It must continue to be examined for years to come. Although there are no

simple answers, we must attempt to arrive at some understanding of how best to utilize our technological resources, as well as how to fund the purchase of new and ever changing equipment. We must also realize that the diversity in how we utilize these resources can actually be a benefit to our students. Different methods and different technologies work in different situations. Finally, we must ensure that the lines of communication are open among all educators to share ideas and effective strategies that can better educate our students for the next century. Only in this manner can we ensure the quality of education we provide our students is at the highest degree possible.

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